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EFFECT OF RATIO BETWEEN VOLUME AND SURFACE AREA OF AIRSHIPS.

By G. A. Crocco.

From "Note di Tecnica Aeronavale," 1923.

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In my preceding communication (See N.A.C.A. Technical Memorandum No. 274) I discussed the effect of the ratio between the volume and surface area of airships on the motive power required to give them a certain velocity and on the amount of fuel necessary for flying a given number of hours. I also explained how the consequent gain in lifting power, obtained by increasing the dimensions, is partially absorbed by structural necessities, leaving, however, within certain limits, a portion of the increase in lifting power available in the form of increased carrying capacity.

The ratio between the volume and the surface area also exerts an influence on other secondary characteristics of airships, which I will here briefly indicate. First of all, I will call attention to the fact that the weights of all accessories, such as suspensions, spare parts and crew, vary with the weight of the power plants. The weight of the fuel containders and the weight of the gas lost during each trip vary with the weight of fuel carried and consumed.

There varies also, in the same favorable ratio, the weight of the apparatus for recovering, in the form of water ballast, the

* From "Note di Tecnica Aeronavale", 1923, pp. 7-10. This paper was read before the "R. Accademia dei Lincei" (Rome, Italy), May 21, 1922.

weight of the fuel consumed or for causing to vary thermally the corresponding lifting power necessary to sustain it, because the sum of these two devices is proportional to the motive power and therefore the percentage of the necessary weight diminishes with increased dimensions, without reaching practically attainable limits.

Other gains depend directly on the area of the envelope and react either on the weight of the structure or its local solidity or related phenomena. The weight of the envelope is affected by two considerations, strength and gas-tightness. The former increases in a greater ratio than the volume and therefore absorbs a greater proportion of the residual lifting power, referred to in my previous paper. The latter can vary in proportion to the area. For some years we have supposed this to be the case. I did not think best, however, to include it in my former paper. I adopted instead, the hypothesis that the portion of the weight of the fabric, rubber, goldbeater's skin or varnish for holding the gas, does not remain constant, but increases in a direct ratio to the dimensions. This hypothesis conduces to a greater local strength of the fabric, greater durability and a smaller osmotic loss of gas.

The osmotic loss is related, in fact, to the quantity of imperviating substance, in the sense that the time required for a given volume of gas to pass through a unit area is proportional to the said quantity. Taking into consideration the whole surface area of an airship constructed according to the foregoing hypothesis, it follows that the percentage of gas renewal required daily for maintaining a given degree of purity varies inversely as the squares of the dimensions. Thus, for example, in an airship having a lifting power of 12 tons, the hydrogen must be completely renewed in a little less than one month, in order to maintain a purity of 19/20, while an airship with a lifting power of 120 tons needs to be renewed only about every five months. One renewal per year would suffice for an airship with a lifting force of 5000 tons. These periods can be about doubled for helium.

Possible weight increments, due, for example, to rain or snow, are proportional to the surface area of the hull. A weight increment of 16%, for example, due to rain on a twelve-ton airship, would amount to less than 9% on a 120-ton type and to only 5% on a 500-ton type. The same principle applies to variations in the lifting power due to sudden changes in temperature. For the same duration of the change, there passes through the envelope a quantity of heat proportional to its area, thus causing a change in the temperature of the gas, and consequently in its lifting power, directly proportional to the ratio between its volume and surface area, i.e. inversely proportional to the dimensions of the airship.

An analogous effect is produced by gusts of wind during flight. For the same intensity and duration, these communicate to the airship an amount of motion proportional to its main cross-section and hence a change in speed inversely proportional to its dimensions. The sensitiveness of an airship to external disturbances is therefore inversely proportional to its lifting power. At the same time and in the same proportion its responsiveness to dynamic control decreases, as also the retarding effect of the air in stopping and in descending. Hence, large airships are necessarily slower in maneuvering.

Since the reactions of the air are proportional to the surface area, while those of the control surfaces vary as the squares of their dimensions, it follows that, for the same speed, the weights of the stiffening members and of the control surfaces vary as the cubes of their dimensions. Hence their percentage remains constant and their moments vary as the fourth power and require heavier structures.

As regards the moments of the disturbing forces, such as those produced by the elevators and rudders, the variation is proportional to the cube of the dimensions. Hence the weight of the portion of the structure designed to withstand these moments also varies as the cubes and its percentage remains constant, as we assumed in our preceding paper. Thence it follows that the stability of flight is better, since the static couples vary more than the volumes. The critical speed increases constantly with increasing dimensions. Thus, for constant flight speed, the oscillation periods vary directly as the dimensions.

The maneuvers of landing and mooring are also worthy of consideration, since they affect the life and utility of large airships. For small airships, these maneuvers are left to the judgment of the commanders and to the physical strength of trained men, but on large airships these maneuvers are accomplished with the aid of machinery. This is rendered possible by the smaller ratio between area and volume, either by the greater relative and absolute disposability or for reasons we will explain. On mooring, after having lost its flight speed with respect to the ground, an airship is subjected to two opposing forces: the thrust of the wind and the strength of the moorings. For the same relative position, the former varies as the area presented. Thus, if the moorings do not generate large moments, all the weight of these and of the resisting portion of the structure varies as the acting force and gains in proportion to the available lifting power. The advantage becomes still more evident, if the moorings are stressed at the proper moment by a suitable lifting force.

Especially in landing, after the cable has been attached to the mooring, there will be created in the latter a stress proportional to the force of the wind, which enables the airship to assume the stable position of a captive balloon and to be brought to the ground without danger. The strength of the cable must therefore be proportional to the force of the wind and also, for the same length, to its own weight. The same is true of the weight of the winches on board and of the corresponding engine parts, as also of the weight of the landing ballast placed in the bow near the cable attachment and released at the proper time for creating, above the latter, a static lifting force in addition to the possible dynamic force.

These considerations are of a theoretical nature, since, if the length of the cable were proportional to the dimensions, its weight would vary in proportion to the volumes and therefore the size of the winches and the motive energy required to operate them. Thus also, if important bending moments are generated, they would diminish the benefits mentioned above. As in every other branch of mechanics, they require a cautious and judicious application.

Similar observations are applicable to the process of mooring. If it is not done under cover, it consists in attaching an airship to the ground in such a way as to leave it free to swing with the wind. The safest method is to attach it throughout its whole length to a movable platform provided with means for swinging with the wind (Invented in 1913, patent No. 138061). In a steady wind, the moorings on this platform then follow the law of the areas.

If it is housed, the movable platform, instead of being oriented with the wind, is designed to move along the axis of the hangar for carrying the airship, which may therefore be exposed to a side wind. Even in such an event, the lateral forces are proportional to the surface area. Thus the combination of the moorings and the lifting forces vary in the same proportion, as likewise the loads with which the platform may need to be ballasted.

As regards the bending moments generated in the above maneuvers, they follow, in general, the law of the cubes and do not therefore affect the proportions of the members designed to withstand them.

It can therefore be claimed, in conclusion, that, even in the majority of the questions which are subordinate but also of practical importance in the operation of airships, there are advantages in increased dimensions; and that, even where there is no apparent advantage, there is no inherent disadvantage.

Translation by Dwight M. Miner,
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